Computational Framework for Studying Cardiovascular Biomechanics in Pathologies

Kexin Lin, Han Li, Igor Inga, Danial Shahmirzadi
Department of Mechanical Engineering

Introduction

Obtaining a quantitative understanding of the aortic biomechanics during health and disease provides significant information that can be used to advance the disease assessment, monitoring and prevention methods. Owing to the advancements in computational power, numerical modeling of the aortic biomechanics has becoming more powerful and effective tools toward quantifying the aortic biomechanics. In this poster, a computational framework has been shown to model various cardiovascular diseases such as blunt Traumatic Aortic Rupture (TAR), Atherosclerosis plaques, Endovascular Aortic Repair (TEVAR), and focal softening, precursor to diseases such as Thoracic Aortic Aneurysm (TAA).

Thoracic Aortic Rupture (TAR): Traumatic Aortic Rupture (TAR) is the leading cause of mortalities in car accidents, affecting more than 3,500 people in US in 2010. According to the National Vital Statistics Report published in 2012, examining the mechanical properties of aortic tissues under damage allow us to gain a better understanding of the damage mechanisms and to improve the severity assessment and prevention schemes on patients with TAR.

Atherosclerosis Plaque: Atherosclerosis plaques are common in thoracic aorta and abdominal aorta. Atherosclerosis plaques could lead to complications such as stroke and coronary heart failure. In this work, a third order polynomial form of the Ogden model is used to express the principle stress and strain.

Acoustic Radiation Force Impulse (ARFI) Imaging: The principle of ARFI imaging is used to express the principle stress and strain. The strain-stress curve of the three layers of the aorta, respectively.

ARFI on Atherosclerosis Plaque: Atherosclerosis plaques are common in thoracic aorta and abdominal aorta. A comparison of mechanical properties between normal artery and atherosclerosis plaque is done. The strain-stress curve of the three layers of the aorta. The stress-strain behavior of the three layers of the aorta, respectively.

ARFI on Atherosclerosis Plaque: One model with 3 layers and plaque: The three layer aorta stent model in abaqus.

Results

Thoracic Endovascular Aortic Repair (TEVAR): TEVAR is a common clinical therapeutic practice for Thoracic Aortic Aneurysm (TAA) and Thoracic Aortic Dissection (TAD), by which an endograft is secured to the interior of the aortic wall in order to help strengthening the weakened areas at the lesion and ensuring the opening of the lumen.

Aortic focal softening: Pulse wave propagation along soft inclusion models (3D waterfall plot) and 2D spatial temporal plots.

Conclusion

Feasibility of using finite element methods to establish a numerical platform for describing cardiovascular dynamic fluid-solid interaction models. Applications of the numerical platform to examine various cardiovascular diseases such as blunt Traumatic Aortic Rupture (TAR), Atherosclerosis plaques, Endovascular Aortic Repair (TEVAR), and focal softening, precursor to diseases such as Thoracic Aortic Aneurysm (TAA).

It was found that numerical model has been effective in providing insights into the phenomena and the results can be used to better interpret the experimental and clinical findings.

Ongoing studies are being conducted to improve the numerical model by incorporating more physiologically-relevant modeling parameters.

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